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Light memory function in a double pin SiC device

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ABSTRACT

A double pi'npin heterostructure based on amorphous SiC has a non linear spectral gain which is a function of the signal wavelength that impinges on its front or back surface. An impulse of a configurable length and amplitude is applied to a 390 nm LED which illuminates one of the sensor surfaces, followed by a time period without any illumination after which an input signal with a different wavelength is impinged upon the front surface. Results show that the intensity and duration of the impulse illumination of the surfaces influences the sensor's response with different output for the same input signal. This paper studies this effect and proposes an application as a short term light memory.

1. Introduction

A memory is a state variable that maintains its value over time. If the value changes it maintains the new value. The time during which the state variable value is recoverable and the number of times it can be read without changing its value define the efficiency of the memory. Different memory technologies can be combined to produce innovative memories like the ones that uses light to read the state variable [1] or molecules to store state variables [2].

The use of a-Si:H/a-SiC:H heterojunctions without filters has been proposed as a two or three color detector [3,4].

The multilayer structure of the SiC sensor presents itself as a temporary memory based on charge stored by illumination of its surfaces. The aim of this document is to provide a study of the memory characteristics of the a-SiC:H/a-Si:H pi'npin device [5] to be used as a logic light memory function.

2. Device design, characterization and operation

The device consists of a double pin a-SiC:H photo detector with front and back optical bias shown in Fig. 1. The device operates within the visible range. Input channels of several wavelengths (R: 626 nm), green (G: 524 nm), blue (B: 470 nm) and violet (V: 400 nm) transmitted together as different bit sequences shine on the front of the device producing a combined electrical output signal named Dark.

Steady state ultra-violet illumination is impinged either on the front or back surfaces of the device acting as optical bias. The corresponding electrical output signal is called Front and Back respectively. The combined optical signal is analyzed by reading out the photocurrent, under either front or back optical bias provided by constant illumination with (390 nm) LEDs [6].

3. Spectral gain

In Fig. 2 the optical gain (α), defined as the ratio between the spectral photocurrent with and without applied optical bias, is displayed under front irradiation. The background intensity (ϕ) was changed between 5 $\mu W\,cm^{-2}$ and 3800 $\mu W\,cm^{-2}$. Results show that the optical gains have opposite behavior under front and back irradiations. Under front irradiation and low flux, the gain is high in the infrared region, presents a well-defined peak at 750 nm and strongly quenches in the visible range.

As the power intensity increases the peak shifts to the visible range and the spectral sensitivity can be deconvoluted into two peaks, one in the red range that slightly increases with the background intensity and another, in the green range, that strongly increases with it. In the blue range the gain is much lower. This shows the controlled long-pass filtering properties of the device.

Depending on the background intensity selects the infrared or the visible spectral ranges; low fluxes select the near infrared region and cuts the visible one, the reddish part of the spectrum is selected at medium fluxes, and high fluxes tune the red/green ranges.

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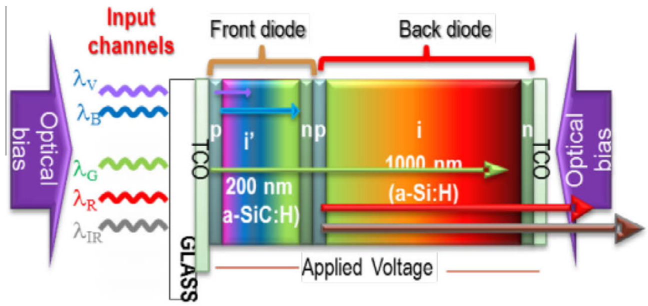

Fig. 1. Device configuration and operation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

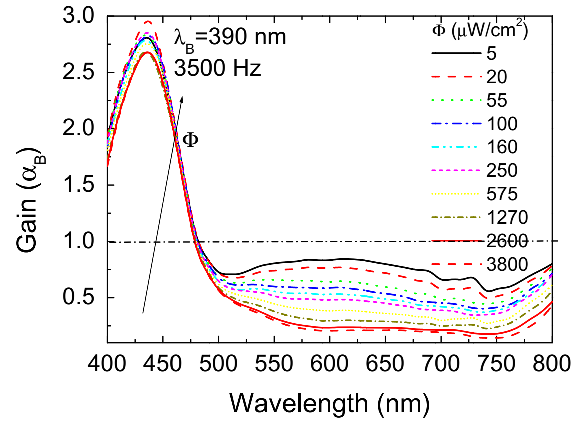

Fig. 3. Spectral gain (α_B) at λ = 390 nm under back irradiation.

Data shown in Figs. 2 and 3 is the result of the spectrum analysis with the sensor electrically biased with −8 V. Readings were accomplished with a monochromator in 10 nm steps from 400 to 800 nm wavelengths. The background illumination was made with a 390 nm LED shining upon the front (front irradiation) and back (back radiation) surface of the LED.

Fig. 3 shows the photocurrent gain under back irradiation. The background intensity (ϕ) was changed between 5 μW cm^{-2} and 3800 μW cm^{-2}. Results show that under back irradiation, the gain is high in the blue region, presents a well-defined peak at 425 nm and strongly quenches above 500 nm.

4. Experimental setup

The optical bias as a steady lighting is used in different applications of this device namely as a WDM (wavelength division multiplexing) communication element and digital light logical functions [7–9].

The relative positioning of the LEDs and the pi'npin device can be visualized in Fig. 4 along with the measuring and control equipment. The PiscaLed system controls the LED currents and their on/off timing patterns.

To use the device as a volatile memory the optical bias paradigm is changed from the usual applications [8] and looked upon as two light Control signals; the Front Control and the Back Control. The operation has three phases, the Control, the Hibernation and the Data phase. During the Control phase only the Front Control and the Back Control signals may be presented to the sensor. The Hibernation phase has no illumination signals; the sensor is in complete darkness. During the Data phase the sensor is subjected to the Data Sense signal. These phases can be represented by switches, shown in Fig. 4.

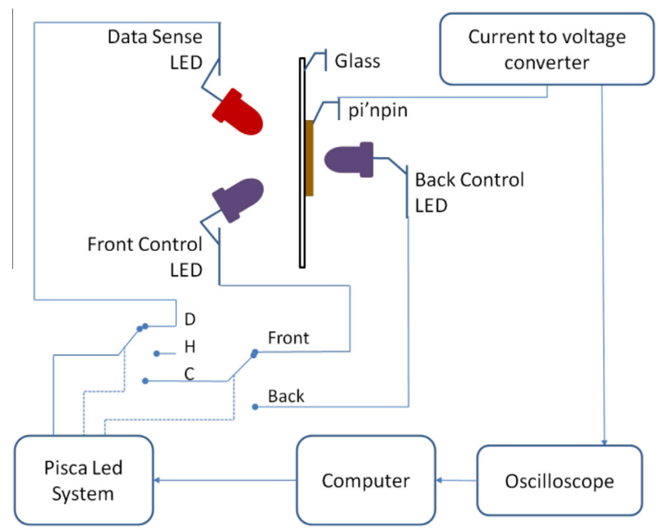

Fig. 4. Experimental setup showing LEDs and their relative position with the p'inpin device and the D, H and C phases as switches.

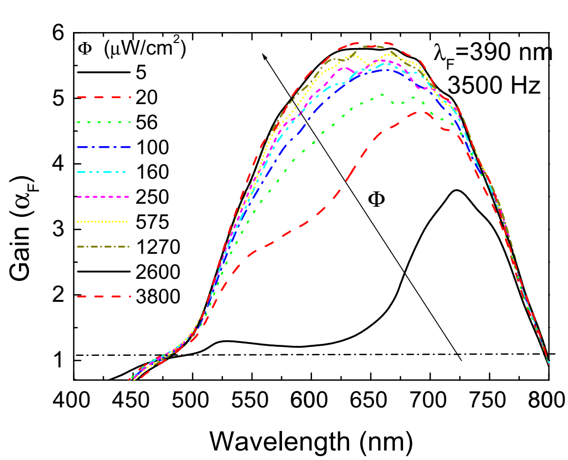

Fig. 2. Spectral gain (α_F) at λ = 390 nm under front irradiation.

The Front and Back Control signals use a 390 nm LED, set with a current intensity of 5 mA and 20 mA respectively. These values differ, so that the output of the pi'npin may be similar. The Data Sense signal is a single 626 nm LED channel pulsed at 6000 Hz, set with a current intensity of 5 mA. These current intensity values were chosen so as to allow a clear visualization of the memory effect.

A signal labeled as Dark is the photocurrent output when there are no Control signals and only the Data Sense signal is applied. It is used as a reference.

The double pi'npin sensor has a noise margin of 8 nA [10].

To introduce the memory theme a simple experiment is shown in Fig. 5a). On the top of the figure, there are the signals to guide the eyes.

The experiment shown in Fig. 5a) is the result of the following sequential actions:

(i) The Data Sense signal is applied and the pi'npin sensor's output is plotted and named Dark in Fig. 5a).
(ii) The Back Control signal is applied during 1 ms, followed by complete darkness during 2 ms, and then the Data Sense signal is applied. The output is plotted and named Back in Fig. 5a).